Navigating a Spacecraft

Background

If you've ever played a sport in which you had to throw a ball to someone who was a moving target, then you can relate to the difficulties of a rocket launch from Earth to Mars. You must throw the ball at exactly the right speed and assume where the catcher will be according to his or her running speed. In the same way, a launch from Earth to Mars must consider the speed of the spacecraft and the speed of Mars in its orbit around the Sun. To add to the complication, Earth too is moving in orbit around the Sun at a different speed. The Earth completes its solar orbit every 365 days while a Martian orbit takes 687 days. This happens for two reasons. The Earth travels faster than Mars and it orbits closer to the Sun, so it has less distance to cover.

The launch must take place when the two planets align with one another which happens every two years. Another launch factor is the rotation of Earth. The launch site must be facing the right direction. Imagine spinning in circles and having to throw the ball to the moving catcher. The ball would need to leave your hand when you are facing a certain direction in order to land in the right place.

While the launch date and time are crucial to a mission's success, survival is another major consideration for a long-duration human mission to Mars. The trip would take six months each way. During this travel time, the crew is exposed to weightlessness, radiation, and other dangers inherent to space travel. One answer to these hurdles may be to make the trips faster. However, there is a tradeoff. A faster trip would result in less exposure to radiation and other dangers, but would demand greater amounts of fuel. One might think of a long journey in a car. Driving faster will use more gas, but time will be saved. Engineers must balance speed with fuel requirements and choose the most efficient, cost-effective plan.

Topic

Plotting Trajectory

Objectives

Students will:

- Compare and contrast the location of Earth and Mars as they orbit around the Sun.
- Use data to plot the paths of spacecraft leaving Earth in the year 2018 for Mars and leaving Mars in 2020 for Earth.

Overview

In this activity students work in pairs to plot the paths (trajectories) of a spacecraft traveling between Earth and Mars in the year 2018 and returning in 2020. These paths use the minimum amount of fuel, and take about six months to travel from one planet to the other.

Key Question

What factors need to be considered when planning a mission to and from Mars?

Key Concepts

- Travel time, distances involved, and location of planets.

Materials & Preparation

- Student Procedure page *Plotting the Paths of Spacecraft*
- Student Sheets, *Earth to Mars* and *Mars to Earth*
- A drawing compass for each group
- Teachers Answer Key

1. Have students share familiar experiences that require aiming at a moving target. Their examples might be passing a football, catching a fly ball, driving vehicles to avoid being hit, or playing dodge ball. Lead students to discuss the how and why of the movements.
2. Have students work in pairs. They may switch jobs for each plotting exercise.

3. Hand out Student Procedure and Student Sheets.
4. Help students become familiar with the data. Check for understanding. It is essential that students understand that Earth and Mars are moving and that the tick marks on the Earth orbit represent the first of each month.
5. Help students plot the first date: June 1, 2018.

   Note: *When plotting the distance from the Sun, the compass point is always put on the Sun; when plotting the distance from Earth, the compass point is put in a different place each time. The point should be put on the tick mark that represents where the Earth will be located on that date.*
6. Make answer keys available to students so they can check their work. If their orbits are not similar to the answer key, encourage them to redo the procedures to find out why they are different.
7. Instruct students to apply the same procedures to plot the return to Earth.
8. Closing discussion should encourage students to think about how a six-month flight affects planning trips to Mars.

Management

This activity can be completed in one class period. Reproduce student sheets and answer keys for students.

Reflection & Discussion

1. What are the orbital challenges of traveling from one planet to another?
2. What could make a spacecraft get to Mars faster?
3. What are some of the problems considered by engineers and scientists as they design trips to Mars?

Transfer/Extension

1. A minimum fuel round trip between Earth and Mars would take about one year. How would this affect planning a trip to Mars? Because of this long time in space, what must happen? What cannot happen? What might happen? These are the questions that mission planners must answer. What are other questions that might be asked about planning trips with minimum fuel orbits?
2. Research and discuss why the trajectory is not a straight line.

Navigating a Spacecraft

Key Question

What factors need to be considered when navigating a spacecraft on a mission to and from Mars?

Introduction

If you wish to travel from one planet in orbit around the Sun to another, you cannot go in a straight line. This activity shows how we can find the actual path travelled by the spacecraft on its way to and from Mars

Student Procedures

1. Locate the following on the Earth to Mars Student Sheet:
   - Earth and Mars orbital paths
   - The Sun
   - Earth and Mars positions on launch date
   - The scale in millions of kilometers (km)
   - Earth and Mars positions on landing date
   - The location of Earth on the first day of each month
2. Perform the following steps for each date in turn:

Read from the table the distance of the spacecraft from the Sun

↓

Use the scale to set your compass to that distance

↓

Place the compass point on the Sun and draw an arc in the space between the orbits of Earth and Mars

↓

Read from the table the distance of the spacecraft from Earth on the same date

↓

Use the scale to set your compass at that distance

↓

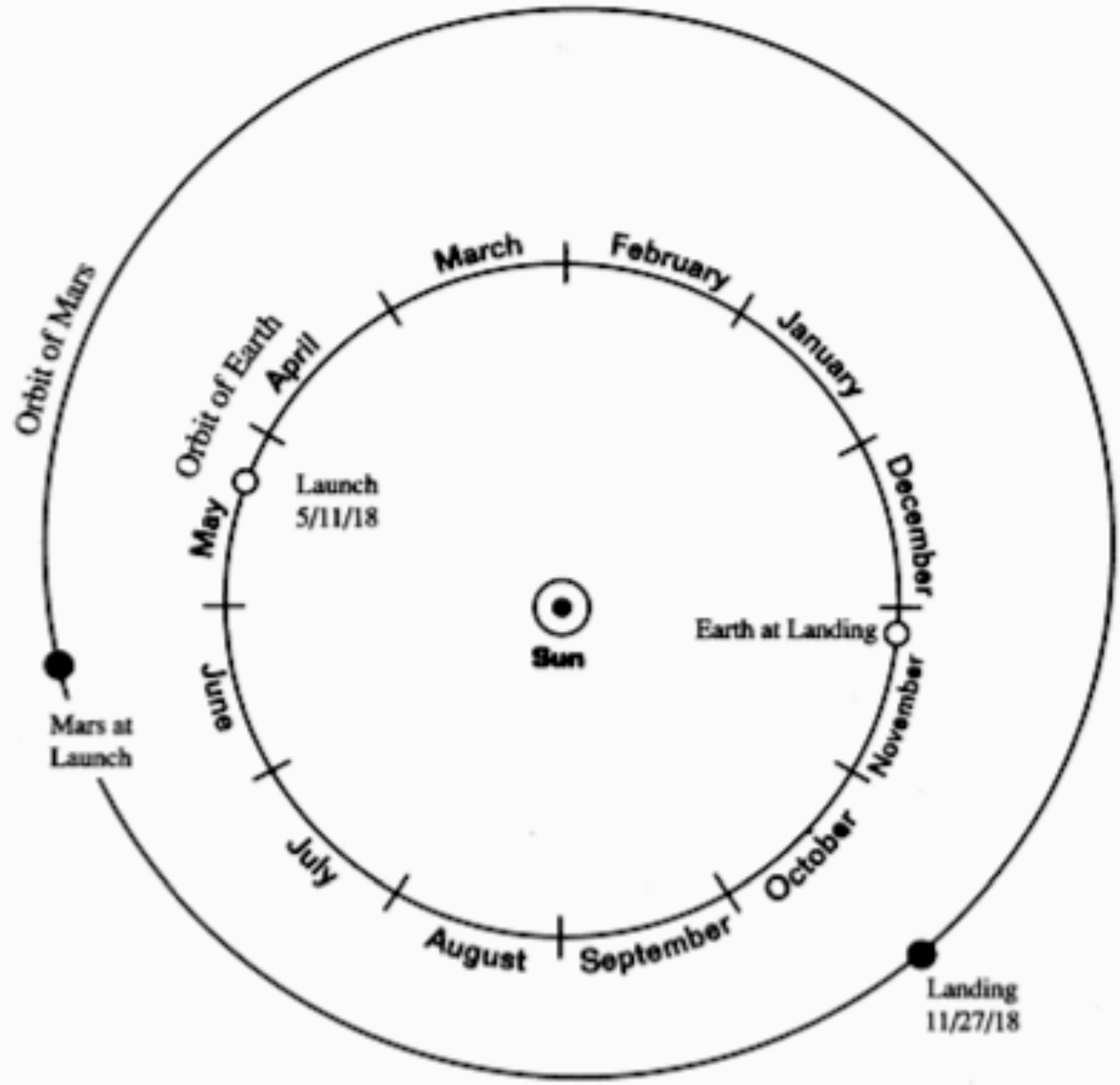
Place the compass point on the earth position for the month and draw an arc to cross the other arc to show where the spacecraft would be found

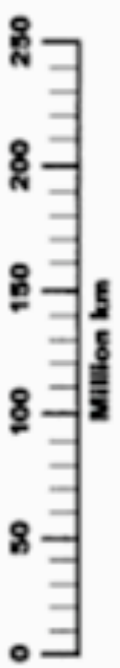
↓

Repeat to find all eight positions for the spacecraft

3. Draw a smooth curve through the points to show the spacecraft trajectory.
4. Apply the same method to plot the trajectory for the return journey using the data about the return trip from Mars to Earth.

Earth To Mars

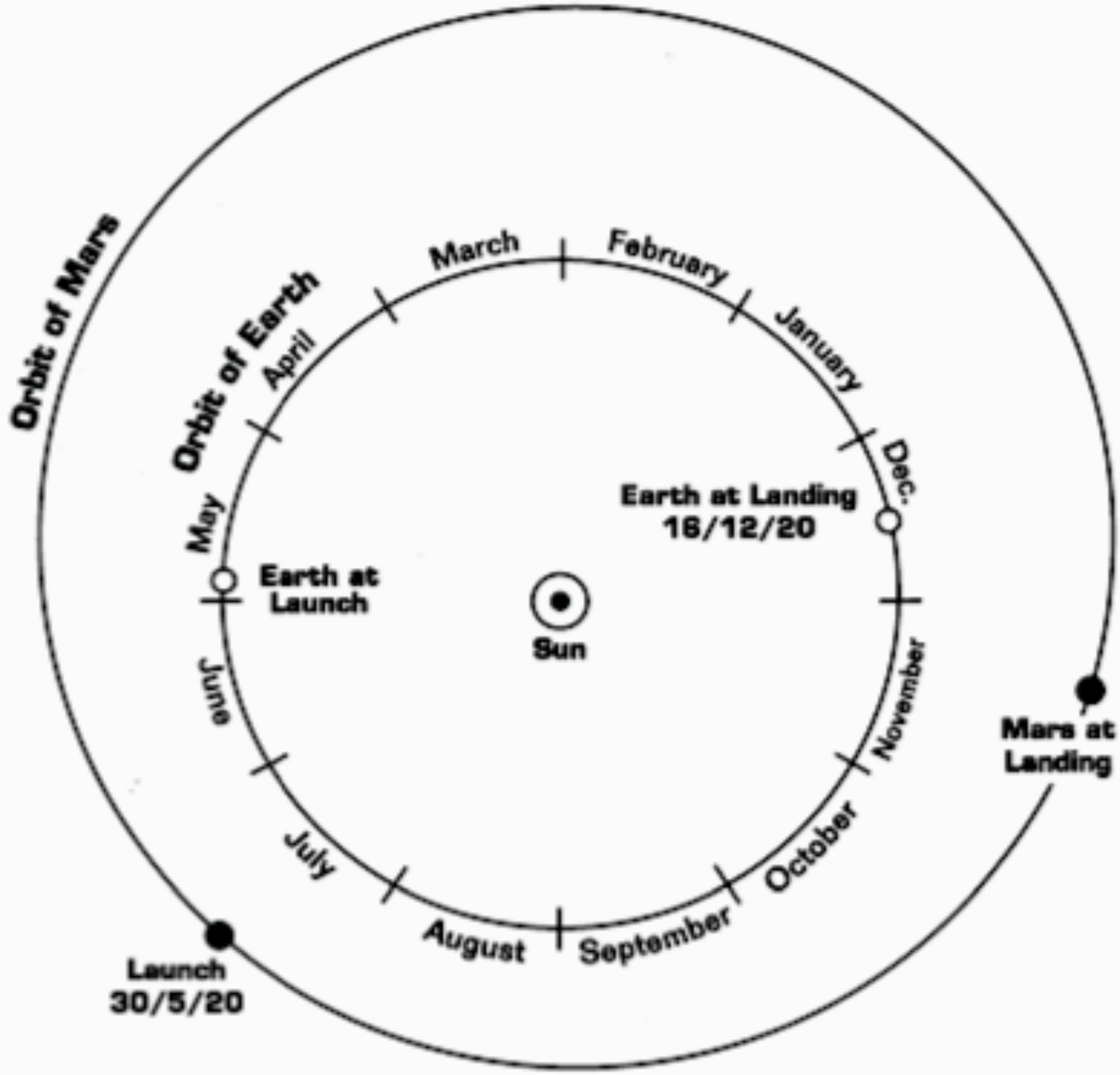




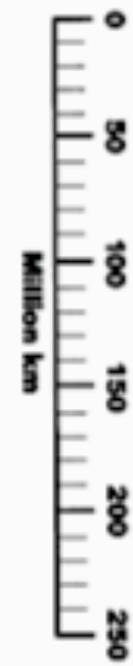
Data Table

Date	Distance from Sun (million km)	Distance from Earth (million km)
May 11, 2018 (Launch from Earth)	150	0
June 1	163	18
July 1	167	28
August 1	175	40
September 1	182	53
October 1	191	70
November 1	207	92
November 27 (Landing on Mars)	216	143

Mars to Earth

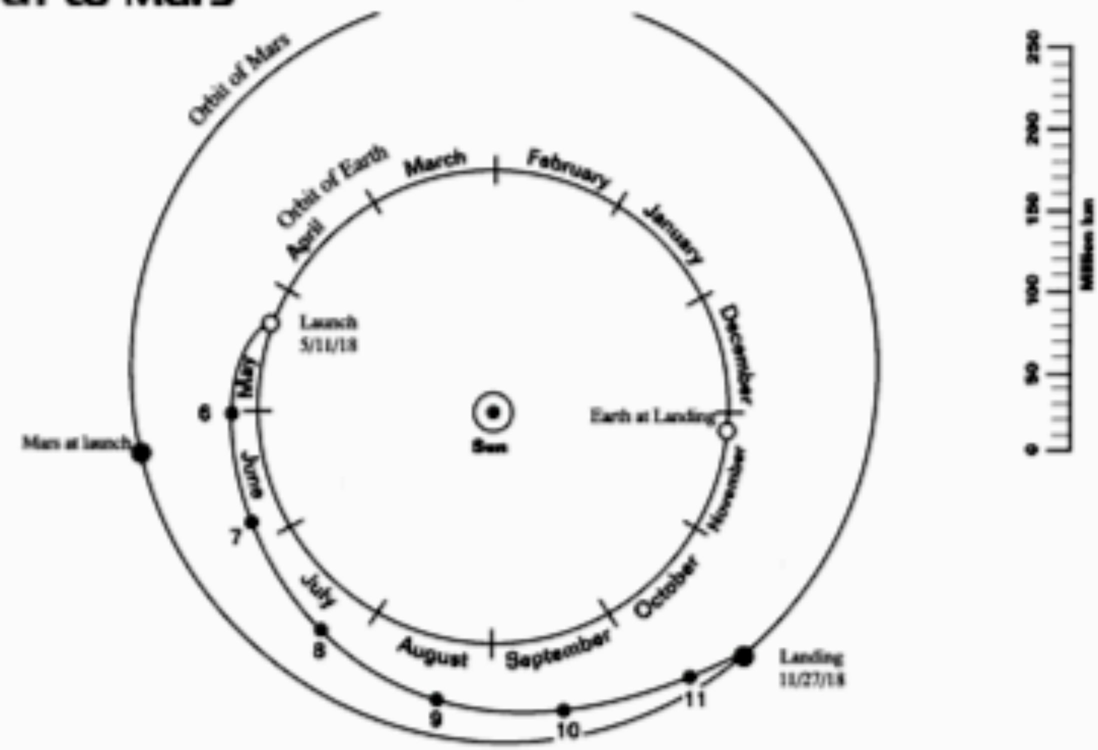


Data Table		
Date	Distance from Sun (million km)	Distance from Earth (million km)
May 30, 2020 (Launch from Mars)	206	155
July 1	198	117
August 1	193	92
September 1	192	73
October 1	191	52
November 1	182	40
December 1	158	15
December 16 (Landing on Earth)	147	0



Answer Key

Earth to Mars



Mars to Earth